

**Effect of temperature on the development and voltinism of the rice stem borer,
Chilo suppressalis (Lepidoptera: Pyralidae) in Taiwan**

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***Chilo suppressalis*, Taiwanese rice stem borer, developmental rate, effective temperature sum, threshold temperature, voltinism, diapause, induction**

Abstract. The effect of temperature on development of populations of the rice stem borer from Hsilo (23.8°N), Tounan (23.7°N) and Pingtung (22.7°N), Taiwan, was investigated. The developmental rates of these populations increased with increasing temperature from 20 to 30°C. The mean developmental periods of eggs, larvae, and male and female pupae in the Hsilo population were 7.7, 33.0, 7.6 and 7.1 days at 25°C under 14L : 10D photoperiod and the theoretical threshold temperatures for development were 8.9, 9.2, 10.4 and 10.5°C, respectively. Effective temperature sums for development were 124, 521, 111 and 103 day-degrees, respectively. These results suggest in the Hsilo population that 4 or 5 generations occur annually in central and southern Taiwan. In the Tounan and Pingtung populations, which require lower effective temperature sums for larval development than the Hsilo population, 5 or 6 generations may occur in a year.

Introduction

Life cycles of insects are regulated by the environmental factors such as photoperiod and temperature (Danilevsky, 1961; Tauber et al., 1986; Danks, 1987; Hodek & Hodková, 1988). The rice stem borer, *Chilo suppressalis* Walker, normally has two generations annually in most parts of Japan and overwinters in diapause (Fukaya, 1950; Ishikura, 1955; Kishino, 1974). The borer undergoes a facultative winter diapause, which is induced by short photoperiods during autumn to winter (Kishino, 1974; Tsumuki, 1990). However, the larval diapause intensities of the rice stem borer from Hsilo, Tounan and Pingtung in Taiwan were very shallow (Tsumuki et al., 1992a,b). The critical day lengths for diapause induction were 9 to 11 hours, i.e. shorter than natural day lengths in winter (Tsumuki et al., 1992a). These results show that the Taiwanese populations overwinter in non-diapause states in central to southern Taiwan. However, there is no information on the temperature sensitivity of the Taiwanese populations.

In this experiment, we examined the sensitivity of the Taiwanese populations to different temperatures.

Material and Methods

The Taiwanese populations of the borer collected from Hsilo (23.8°N), Tounan (23.7°N) and Pingtung (22.7°N) were reared on rice seedlings at 25°C under 14L : 10D photoperiod as stock cultures (Tsumuki et al., 1992a). Egg masses were collected daily from the stock cultures and transferred to each temperature. Hatching of the eggs was observed every day. Approximately 100 newly-emerged larvae were put on rice seedlings and reared at each temperature. Pupae were counted every week when the seedlings were exchanged. The pupae obtained daily from the stock cultures were transferred to each temperature and adult emergence was observed every day. The threshold temperatures for development of the eggs, larvae and pupae were determined as the X-intercept of the linear equation relating temperatures to developmental rates.

Results

Fig. 1 shows the developmental rates of egg, larva and pupa of the Hsilo population at different temperatures under 14L : 8D. Their developmental periods reduce with increasing temperature from 20 to 30°C. The mean developmental periods of the eggs, larvae, and male and female pupae were 7.7, 33.0, 7.6 and 7.1 days at 25°C under 14L : 8D, respectively. The theoretical threshold temperatures for

development were 8.9, 9.2, 10.4 and 10.5°C, respectively. From these results, 124, 521, 111 and 103 day-degrees were obtained as the effective temperature sums for development of eggs, larvae, and male and female pupae, respectively. The mean larval developmental periods of the Tounan and Pingtong populations were 32.0 and 27.0 days at 25°C under 14L : 10D, respectively (Figs 2 and 3). The theoretical threshold temperatures for larval development were 9.5 and 9.7°C and their effective accumulative temperatures were 496 and 413 day-degrees, respectively. In all populations tested the high values of correlation "r" indicate that the data fit the linear model well.

Discussion

Larvae of the Japanese rice stem borer respond to day length as a primary environmental signal to regulate diapause (Inoue & Kamano, 1957; Kishino, 1974; Tsumuki, 1990). However, day length was of little importance for programming the diapause of the borer in central and southern Taiwan, because natural day length hardly induced diapause in winter (Tsumuki et al., 1992a). In fact, the borer spends winter without diapause in fields in central and southern Taiwan (Chang, 1968). Furthermore, the dry season may not serve as a signal for the diapause induction of the borer (Tsumuki et al., 1992a). Consequently, the active phase of the life cycle in these Taiwanese populations may be regulated only by ambient temperatures.

The theoretical threshold temperatures for development of egg and larva in the Taiwanese populations tested are somewhat lower than those of the Japanese ones (Inoue & Kamano, 1957; Kishino, 1974). In the same species the theoretical threshold temperature for development varies with different ecotypes and geographic locations (Utida, 1957). The threshold temperatures for larvae of the Taiwanese populations tested were 9.2 to 9.7°C. The monthly normals of daily minimum air temperatures in Taichung (24.1°N) and Tainan (22.6°N) winter are 11.5 and 12.7°C, respectively (Kurahashi et al., 1964), which are above the threshold temperatures for larval development of these Taiwanese populations. In most parts of Japan, however, the monthly normals of daily minimum air temperature in winter are below 0°C (Kurahashi et al., 1964). These results suggest that the active phase of the borer life cycle is maintained throughout the year in central and southern Taiwan, whereas in Japan the larvae enter diapause and do not develop during winter (Tsumuki, 1990).

Threshold temperatures for larval development were almost the same among the Taiwanese

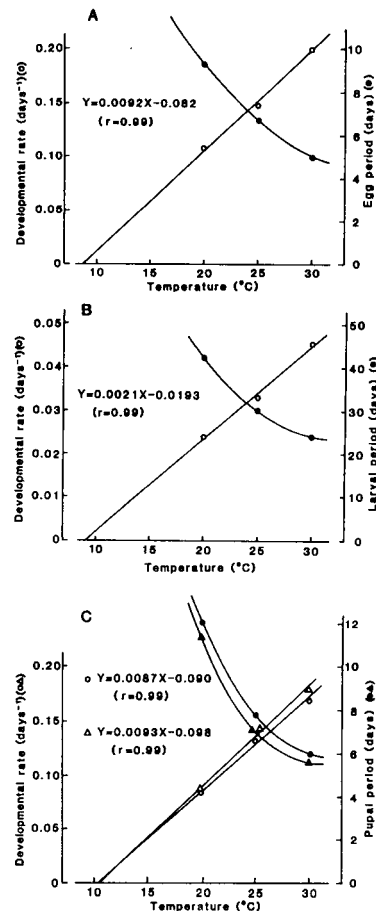


Fig. 1. Effect of temperature on the development of egg, larva and pupa in the Hsilo population of *Chilo suppressalis*. A: egg, B: larva and C: pupa (△▲ – male, ○● – female).

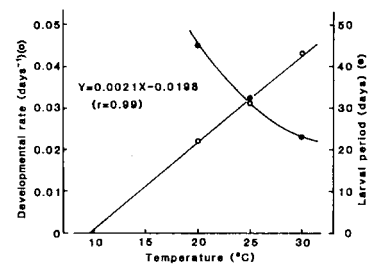


Fig. 2. Effect of temperature on larval development in the Tounan population of *Chilo suppressalis*.

populations tested, whereas the effective temperature sum of the Pingtung population was lower than that of the Hsilo and Tounan populations at 25°C, showing that larval development is faster at lower latitudes, increasing thus the number of annual generations.

The possible number of generations of the borer in a year can be estimated from the threshold temperature and total effective temperature for completing a generation, and annual normals (Utida, 1957). Annual normals are 22.2°C in Taichung and 23.2°C in Tainan (Kurahashi et al., 1964). The weighted mean threshold temperature for development from egg to adult was 9.3°C for the Hsilo population. The Hsilo population required 859 day-degrees for the development of egg to adult. Consequently, the possible number of development cycles from egg to adult in the Hsilo population is 5.5 and 5.9 in Taichung and Tainan in a year, respectively. However, the time for oviposition has to be included; adults mated within one or two days after emergence at 25°C and oviposited. From these results the maximum possible number of annual generations in the Hsilo population in Taichung and Tainan is 4 or 5. The Pingtung population, which has lower larval effective temperature sums than the Hsilo population, might have 5 or 6 annual generations in Taichung and Tainan. These experimental results are consistent with actual seasonal prevalence of the moths in the fields (Chang, 1968) and may be used as reference data for forecasting occurrence of the borer in central and southern Taiwan.

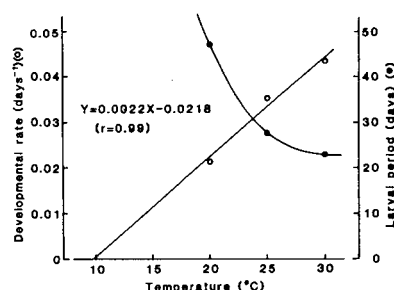


Fig. 3. Effect of temperature on larval development in the Pingtung population of *Chilo suppressalis*.

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